IMPACTS OF IRRIGATED LEGUME-BASED CROPPING ON RHIZOBIA DIVERSITY, INSECT POLLINATORS, AND SOIL SEED BANK IN A RANGELAND ECOSYSTEM, ISINYA DISTRICT, KENYA

USING THE SUSTAINABLE PREFERRED-STABLE-STATE MODEL IN A NARRATIVE

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Abstract: Range assessment in the past involved the monitoring of the growing condition of natural vegetation, and thus the prospect for yield of animal products. The assumptions were: (1) that land will be managed to maintain range ecology vegetation to the exclusion of annual food crops, (2) that land carrying capacity assessment will provide adequate information on range trend and condition, and (3) that flux in community is merely produced through grazing, burning, and clearing, and climax is expected to re-establish through natural sequence of regenerations. This approach in range management came under scrutiny in Africa from the 1980s due to a better appreciation of the multifunctional use of the range.

The old approach had been successful in the past, but today they can only produce a partial picture of what is happening in the tropical rangelands. The present reality is that population pressure is causing people to migrate from the humid regions and settling in rangelands, bringing with them non-traditional range agricultural practices; which some pastoralists are forced by circumstances to also acquire and incorporate in order to subsist on the range. In East Africa this social adjustment has been helped by a better access to modern agricultural technology such as groundwater irrigation and improved cultivars developed for drylands. Crop production - alone or accompanied by livestock keeping - has become viable, profitable and in practice on the range. Grain outputs are supplementing if not replacing milk and meat as sources of nutrition and income for range households. Carrying capacity based on number of livestock or forage production is no longer adequate for range assessment. What is needed now is a total assessment of range conditions using approaches that reflect the current rangeland uses. Where mixed farming is practiced, an overall range assessment must look at the total sustainable yield of grains and animal products. Clearing and cultivation together with the biodiversity implications must now be put on the same level as burning and grazing as factors of range assessment. The biodiversity implications of irrigated farming and the multifuntionality of the East African rangelands must now come under increasing focus.

The scale of assessment now needed in the East African rangelands calls for a deviation from the normal management that depends too highly on the Clementsian theory of vegetation succession, which tends to promote one operational state. The outcome of this old approach will not meet utilitarian and economic needs of the land owner today. The production ecosystem it promotes seems over determined by natural environmental conditions, and the approach has not fully factored in the human ability to change the fortunes of the dryland through innovation and progress in technology. The rangeland inhabitants of East Africa are re-inventing and redefining the range landuse potential by embracing appropriate and increasingly affordable agricultural technology, such as simple irrigation systems and biotechnology of improved cultivar for dryland farming. Under the changing demographic structure the system is more complex than ever; so rather than working to maintain one stable operational state, range management that leans towards non-equilibrium concepts such as the state-and transition model or the self-organizing holarchic open system theory will provide a better idea of how condition and trends in the East African rangelands can be assessed. Drawing from these theories, this study proposes the sustainable preferred-stable-state model as an approach for regional range monitoring and assessment.

Keywords: African rangelands, rhizobia assessment, climatic limitations, vegetation, irrigation, sustainable preferred-stable-state.

The study examines the condition and pattern of change resulting from groundwater irrigation in legume-based cropping system on the rangeland of Isinya District as a practical example of how the sustainable preferred-stable-state model can be applied. It compares the biodiversities of pollinator insects and rhizobia, as well as the soil seed bank reserves between the cultivated areas and the open range.

The study area is a typical example of eastern African rangelands where adaptation to agro-pastoral practices is growing rapidly. It is among the Kenyan priority area for agricultural development and poverty eradication. Isinya District is a peri-urban area on the fringe of the Nairobi National Park, thus a dispersal area and migratory corridor for wildlife. Due to rapidly rising human population, local food production is becoming more of social and economic necessity. However, vast available area of land in the area has in the past been managed more for livestock development due to climatic and vegetational conditions. Now the community is tapping into the abundant groundwater supply through boreholes and other means to support irrigated grain production. The grains are supplementing and even providing protein alternative in household diets, but is there a biodiversity implication lying beneath this?

The research concerns are: whether rhizobia diversity increase in rangelands through increased soil moisture and the introduction of grain legume crops; how pollinator insect diversity could vary among range types; and if soil-seed pool of natural herbaceous plants decline with continuous irrigation and weeding. Data will be collected from four exclosure plots representing different range operational states. Soil samples from spatially randomized plots located within the study area will be collected over two seasons, and analysed to compare changes between the range types as a response to changing soil moisture and the introduction of grain legume crops. The attributes include vegetation analysis, rhizobia diversity assessment, soil nitrogen and phosphorus, pollinator insect diversity, soil seed bank assessment.

I. Overview

There is a growing recognition that the traditional approach of range monitoring based on assessment of climax type vegetation, and the related animal carrying capacity per hectare can now produce only a partial picture of the East African rangeland. There is a good reason for this. The change in occupancy system that permits land subdivision into smaller and affordable parcels has encouraged the migration and settlement of people from high density areas. Areas where livestock and wild animals previously roamed freely are now partly occupied by residential houses, and prime grazing sites are being fragmented as a result. Limited open range and land fragmentation mean that mobility of animals is hampered, and their exploitation from the diversity of forage available in heterogeneity of landscapes is hampered. The result is poor quality of livestock output and declining income for herdsmen.

The situation is complicated further by the economic returns of the rangelands, which are adversely affected by weather unpredictability most critically felt as droughts over the recent years. Thus, perceiving the range to be of less economic worth, the pastoralists are willing to sell off portions of their land to immigrants. As new inhabitants come in and settle, many of them resort to fencing to secure their property, thus leading to more fragmentation. Then to increase the benefit of land ownership, some of the immigrants exploit the available blue water for crop production within the fragmented units of fenced properties. Some of the indigenous pastoralists are willing to emulate this perceived success by adopting the cropping methods of the immigrant agriculturalists as an alternative or supplementary to livestock keeping.

This shift has coincided with and benefited from the times of better access to agricultural credit, irrigation technology and cultivars improved for dryland farming, brought about by the intervention of NGOs, the private sector, science and research, all of whom can only function well under a, perhaps, better listening government. Overall, shift is working and proving more economically viable than the normal range agricultural landuse weighed down by natural environmental variables and anthropogenic changes in the physical landscape.

In the final analysis, the agricultural outlook of the Isinya rangelands is changing from a predominant pastoral landscape to patches and fragments of cultivated lands mixed with remnant of the traditional transhumnce pastoralism. At the landscape level therefore, the range now shows a picture of agropastoral-ecological system. The conventional definitions based on traditional agricultural landuse potential cannot now be adequate to describe the changing East African rangelands, since it is no longer a contiguous area managed primarily for livestock and animal production. As such there must be a 'rethink' in range assessment, at least in this region.

The emerging system of rangeland farming cannot be wished away because it is socially driven, impacts on the local political-economy, and has a long-term implication on regional biogeography. Political-economy is in the sense that it provides direct employment for people, particularly rural and peri-urban women who provide bulk of the farm labour. One consideration is that pastoral women are learning new skills, which will potentially help them to adjust to more sedentary life and all that comes with it, including better access to education for the children.

Definitions based on the adaptive ecosystem approach, and the range assessment that considers the current practical uses of the land will provide a more acceptable description of the East African rangelands. As such, range management in the region must now rely less and less on the Clementsian based approaches, which mostly focus on the monitoring of land carrying capacity of wildlife and livestock and fire ecology for rangeland assessment. As it is no longer feasible to maintain the mind frame that the range can be managed to maintain one stable state – given the current social and ecological changes – management approaches that rely on non-equilibrium theories would provide more realistic assessment of the East African dryland.

Adoption of the Clementsian approaches was informed by the visible environmental conditions that limited landuse to the amount of budgetable surface water mainly available through rainfalls. This tight moisture regime is now being circumvented through a better access to groundwater, available in boreholes and streams. Water from these sources is used to support agricultural practices that are different from pastoralism, which is the traditional form of farming on rangelands. Progress in technology has helped community innovation to generate multiple functional states. As a result, system non-equilibrium models such as the state-and-transition models as described by [8] or [6] and the self-organizing holarchic open system (SOHO) described by [29] will provided a more useful assessment of the East African rangelands today. This study proposes the sustainable preferred-stable-state model as a system non-equilibrium approach in the assessment of conditions and trend in the East African rangelands.

The proposed sustainable preferred-stable-state model is best described using a practical case as provided by this study. The study examines landuse change through groundwater irrigation to support a legume-based rotational cropping system in a Kenyan rangeland, and how these impact on the diversity of pollinator insects, compatible rhizobia, and seed pool in the soil.

The study area is the newly created Isinya Distirct of Kenya. The area was a typical rangeland, classified as Kenyan Ecological Zone IV according to Pratt and Gwynne *et al* (1977). It is therefore characterized by average annual rainfall of about 550 mm, high day time temperature, and high surface evaporation. The soils are mostly shallow and underlain by kapiti phonolite basement rocks, which make the establishment of trees difficult. The vegetation feature is therefore savannah, which is naturally suited for livestock and wild herbivores production. The area is only about 40 minutes south of Nairobi by a car drive. Although previously a wildlife migratory corridor between the Nairobi and Amboseli National Parks, the Greater Kajiado area is witnessing rapid change in landownership driven by peri-urbanization of sectors within and outside it. Agricultural landuse in the area tends to be shifting towards crop production, as livestock herding is less and less viable. The physiography of the area characterized by abundant flow of groundwater is helping to make this shift possible.

Study sites have been selected within the area based on the criteria of 4 range types: (a) open range, (b) exclosure range with livestock, (c) exclosure with rainfed crops, and (d) exclosure with crops under irrigation. Sites (d) is selected only from among irrigated open crop fields with grain legumes.

Study attributes include rhizobia and pollinator insects diversity, soil seed bank, as well as soil moisture assessments. The variation in the attributes among the range types will be quantified using statistical models. Further laboratory analysis will be done on soil samples taken from the sites to determine the effects of changing moisture regime and the introduction of legume crops on soil nitrogen and phosphorous compositions.

Study is expected to show that irrigated farming is leading to a significant change in number and abundance of pollinator insects and rhizobia in the area due to constant soil-moisture supply. It also expects that the presence of flowery legumes will attract more pollinator insects, thereby increasing their diversity. Further, it expects that soil seed bank will erode over time [2] due to constant nascent stage destruction of natural plants as weeds in the cultivated sites. The assumption is that increased soil moisture breaks dormancy of seeds thereby causing them to germinate, only for the emergent plants to be destroyed before their lifecycle completion (seeding of next generation) – thus leading to the erosion of viable seeds in the soil.

The research interest in the three attribute is due to the potential to increase crop output while conserving natural range vegetation in form of seeds within the fragments of cultivated land. High diversity of compatible rhizobia will lead to increase in biological nitrofixation for better growth of legumes, companion crop, and sequential plants. Greater diversity of pollinator insect will bring about higher yield of grains. While these will make farming more affordable and profitable, abundant soil seed reserve will lead to quick successional regeneration of natural vegetation in period of fallow or abandonment. Such regeneration will ensure the survival of native herbaceous which have co-evolved with the animals and have made grazing possible in support of traditional lifestyle of the indigenous pastoralists. With success, dryland farming can be made more productive while limiting loss of natural plant biodiversity, thus qualifying as range management rather than outright ecosystem conversion.

If the study finds that compatible rhizobia abundance has increased in the legume cultivated area, then recommendation can be made for repeated, sequential cropping of pulse to benefit from the robust environment of the bacteria. If there's a negative or zero change in abundance in effective rhizobia, then recommendations can be made for the introduction of inoculants at legume planting to increase root nodulation and nitrogen fixation. Similarly, farmers can be encouraged to keep apiary in order to benefit from increased abundance of pollinator bees as a result of abundant nectar supply in the legume fields.

Knowledge of soil seed pool will inform managers about how well the ecosystem is doing [2] [15], and therefore the decision about the need for reseeding to generate vegetaional succession during fallow or lack of that requirement thereof. Study will take the form of a research paper to be presented in a journal format.

The statement about landuse in the area is not universal, as demographic change through immigration is also bringing about non-agricultural landuse transformations. However the study is only interested in agricultural landuse change and even this is not homogenous. First it depends on the availability of groundwater for irrigation, which mainly comes through boreholes sunk by those households that can afford it. Other sources of blue water include the Isinya River which is exploited to grow market gardening crops. This groundwater source only serves households located adjacent to the river. People further afield rely more on boreholes and tanker supplied water for domestic and other uses. Secondly, the farming activities is not always directed towards food production, since some of the large farms mainly produce cut roses as well as other forms of flowers and horticultural produces for export. Moreover, it is important to clarify that the purpose of crop production in the area is not always for local food security as some legumes such as French beans and runner beans are mainly for the export market. The production of cash crops is justifiable by the fact that it brings in foreign exchange and generally pays more to offset the cost of borehole water pumping.

Furthermore, it is important to mention the growing practice of greenhouse farming in the area (even though this will not be highlighted in this paper). This growing system of modern farming provides renewed hope for food security in the region given the generally better water efficiency and lower exposure to crop pest and diseases in greenhouses. However it is scaled out of this study because it is not amenable to all the attributes on focus. For example, the issue of pollinator insects and their impacts on crop yields is best expressed in field cropping sites, and greenhouse sites can only provide comparative data on plant yields. Greenhouse farming is posed to grow in Kenya due to several reasons, however, field cropping will always be a common practice as photoperiodicity is more than adequate and the need to mimic a suitable heat climate is not a limiting factor in agricultural production in East Africa.

II. APPROACH

Rangelands of the world are under considerable change, and so should the global strategies for range management [3], [5], [21], 41, [45], [46], [54]. The conventional definitions of the rangeland based on landuse potential emphasize the inherent climatic, vegetational and soil conditions of a place (Pratt and Gwynne, 1977); [23]. They tend to ignore many examples of peoples' ability to alter the environment through technology; as such drylands continue to be undervalued as places of low agricultural potential.

Due to climatic limitations, the East African rangelands have been best suited for livestock and animal productions in the past. Yet, recent socio-ecological changes have revealed that management can create in these drylands new forms agro-ecological production ecosystems whose analysis require more than the normal potential-based indicators [6].

In general, water availability is the key environmental influence which determines the organizational state of ecosystems [29] and old definitions based on landuse potential rely on inherent surface water deficiency of rangelands [3]. Yet, many rangelands of East Africa overlie areas characterized by abundant groundwater flow [3] [16]. Landuse potential can be used as a criterion for definition of rangeland... But it must be the potential at the present state of technology and community innovation. The old definitions, which warrant the use of carrying capacity of animal and the growing condition of natural vegetation for trend assessment, can no longer satisfy the various new uses of the rangeland in East Africa [5], [23], [54].

The normal approaches assume that proper range management necessarily result in the maintenance of a steady-state [29]. They over-rely on the old 'Clementsian' view of ecological system where succession to climax community is expected to always emerge and perpetuate range ecosystem in a stable-state [28]. For example, adopting this normal framework, [23]) defined rangeland condition as the relation between the present and potential range health. Herlocker (1999) carries a lot of weight as it dominated range monitoring in the East African region in the 2000s, and it was therefore significant that its reference to vegetation was with regards to native pasture, even though the introduction of agricultural plants was becoming evident by the 1990s [39]. Without any significant shift in approach, therefore, monitoring of range trend was done through the assessments of the conditions of native plant species, not only in East Africa but around the world [53]. Yet, according to [5], focusing on small things like changes in the soil composition may provide a better indication of permanency or reversibility of rangeland degradation. This change can occur when vegetation composition is altered through the introduction of agricultural plant biodiversity.

Many problems associated with the climax-based approach of range monitoring had made shift in paradigm unavoidable (Smith, 1989; Wilson 1989; Friedel 1991; Laycok, 1991 quoted in [55]. According to [29], the old approaches mostly fall under the S-science framework, where explanation is in terms of homeostatic casual loop in which naturalists hope that system will self-adjust to a preferred stable-state. Such approaches do not suit the needs of land management in East Africa where range assessment must now also consider the various ways in which land potential are being enhanced, for example through the use of organic or inorganic fertilizers, and irrigation.

Range monitoring based on feedback loop that maintains a steady-state faces some problems in East Africa today. First, successional return to climax community is no longer possible in some areas without intensive human inputs (Westoby *et al*., 1979; Allen-Diaz and Bartolome, 1998 in [32]) such as through reseeding of eroded surfaces. The old approaches do not fully consider what happens when the system state comes under a considerable human disturbance, such as the encountering of a deliberate and drastic stochastic deflection through vegetation replacement [29]. Second, the return to climax is not always the goal of local management where the immediate need is food security [32].

This problem is not really peculiar to the East Africa region, as scholars elsewhere similarly recognized the problem at different scales of local manifestation. Accordingly, in the 1990s scholars began calling for new ways to deal with complex ecosystems [37] like rangelands. New approaches, such as the self-organizing holarchic open system (SOHO) paradigm as propounded by [28] as well as [29], and the system noneequilibrium [13] updated and applied as state-and-transition models (STMs) described by [6] and [27] are better suited to analyse the current complex conditions of the East African rangelands. The old system of a strictly science based definition of ecological integrity, which can be applied irrespective of circumstances, cannot, in principle, be satisfied; or integrity has to be redefined [5] [29]. The call is for a post-normal range management that is forward looking, multiple uses oriented, and defines range potential at the present state of technology. With respect to East Africa, this study proposes sustainable-preferred-state model as a means of analyzing the increasingly fragmented units of the rangelands. The model is best explained through example from an experimental site.

III. RESEARCH CONCERN

Thanks to technology, the use of range now goes beyond the traditional management to optimize yields of animal products and tourism [16] [48]. Other landuses such as crop production, horticulture, poultry, and industrial production now compete with livestock and wildlife for space in the rangelands of the world [20]. Also growing is the practice of confined animal meat production. Success in alternative agro landuse shift has been partly attributed to better access to specialized seed varieties which have a better response to fertilizer inputs [16], [46], as well as due to cheaper access to irrigation systems [50], [16]. Given the lessons learned from the recent East African droughts, it makes more and more economic sense to produce at the lower trophic level to reduce periods of risk associated with weather unpredictability normally faced by livestock production in East Africa.

The exact natures of transformation in the rangelands of the world reflect local priorities, but the bigger picture is that of changing ecological and cultural landscapes [32]. Demographic change resulting from immigration of people from high population areas [27], and the environmental conditions that discourage pastoral nomadism are driving landuse change in the East African drylands. Knowledge of science and technology and their input is helping community to manage the resulting shift in livelihood strategy [16], [27] [45], [54].

The practice of dryland cultivation has become more possible and economically sound. What is required now is knowledge that makes the system more sustainable and the ecosystem more resilient to long term changes. Normal range management must come to terms with the current reality of change and begin to adopt integrated, multidisciplinary approach that reflects the economic, social and ecological objectives of the rangeland inhabitants. It cannot have a preferred landuse or ecosystem state, since every system have merits and scientists can only inform about the different tradeoffs each state represent [29]. This is in agreement with [43], which says that: “For the land user cash in the bank is a better indicator of range condition; while for the ecologist, range health is dependent on species vigour and proportions”.

The emerging approach adopts multiple uses of land [24], [49], [38] because, viewed from management perspective, the rangelands of East Africa now also contain patches and fragments of cultivated lands. Observed at the landscape scale, the region is still predominantly a livestock production area, however crops-livestock management are now common sites in the rangelands where only livestock and wildlife roamed freely in the past [39]. In the final analysis, shift to multifunctionality [40] is gaining a widespread acceptance among land owners in East Africa and it could be an answer for food insecurity in the dry regions.

With the emerging shift, the conservation concerns are those of sustainability and resilience of the new systems. The here and now biodiversity concern is of economic nature; it is of whether the new system has a diversified enough ecological complex to sustain the economic and other needs of the land manager. The ecological concern is about the sustainability of the total-system [21]. It is about how resilient the new system is in the support of possible future return to the original stable-state [29], which has sustained the

lifestyle of the indigenous people in a livestock grazing culture dependent on natural plants diversity of the dryland. The new mindscape in science must help shift to the emerging principle of adaptive ecosystem approach [29] to produce more food at a minimal cost to natural plant biodiversity.

The study examines the legume-based rotational farming system under irrigation and its impact on the rhizobia, pollinator insects, and soil seed bank diversity in Isinya District. This farming system is selected for the change at the ecological site due to new soil moisture regime brought about by groundwater irrigation; the flowery quality of legumes and its affinity with pollinator insects; and for the symbiotic relationship between rhizobia and root system of legumes, which is likely to vary under the new conditions. The study also examines the relationship between weeding and the erosion of seed bank in the cultivated fields.

On the one hand, both pollinator insects and rhizobia diversities are under focus due to their economic implication for farm management: Rhizobia for their ability to fix soil nitrogen in symbiosis with legumes, for the benefit of companion as well as sequential plants [4], [19], [36]; and pollinator insects due to their inherent ability to increase grain yield through efficient pollination of the flowering crops, companion crops, and sequential crops [13], [18].

On the other hand, soil seed bank has been considered because it is a source of ecological resilience following range clearing and cultivation [2] [15]. If sufficient viable seeds are left in the soil at fallow period or time of abandonment, they may germinate and lead a successional restoration to a stable-state resembling the old one with features of savannah grassland, which supports animal production and community’s lifestyle.

IV. Theoretical And Conceptual Framework

The traditional most desirable agricultural use of rangeland has been the production of animal products in a management practice agreeable with range natural resources management. Social and economic changes of recent times have, however, necessitated and also provided a wider range of choices in rangeland use beyond the normal livestock production and wildlife conservation/management. With more options available, the ultimate landuse decision now depends on the choice of the landowner. The overriding factors guiding this choice include the utilitarian and/or economic needs of the rangeland user under the prevailing social, economic, political and environmental conditions.

State- and-Transition Model

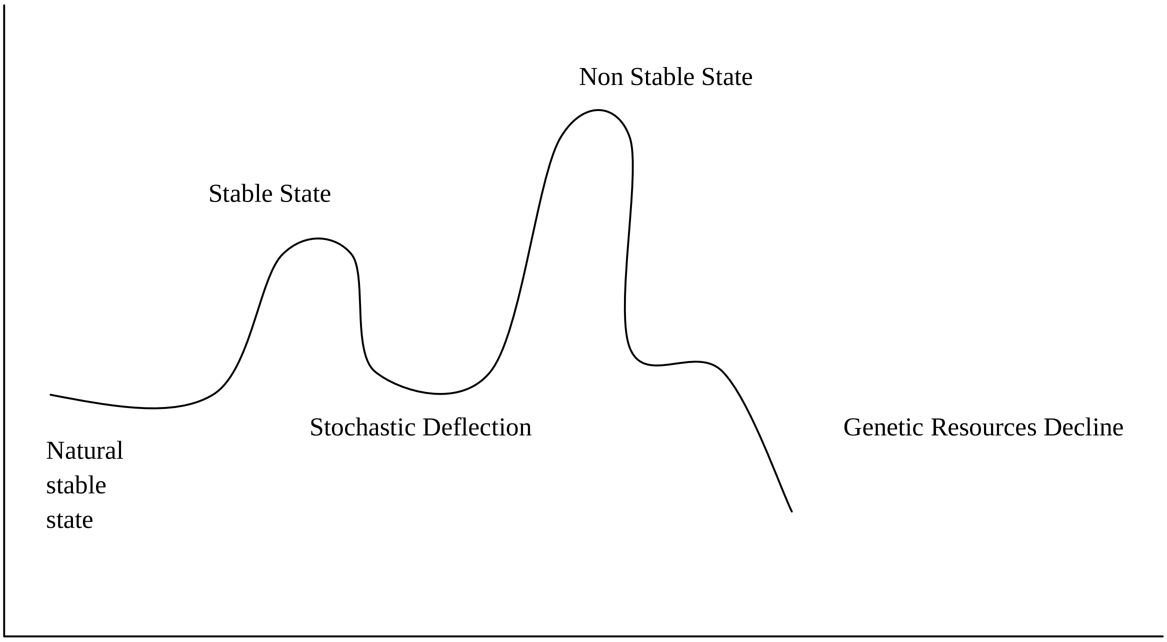

Figure 1

Source: Modified from DeAngelis *et al* (1987)

Sustainable-Preferred-State Model

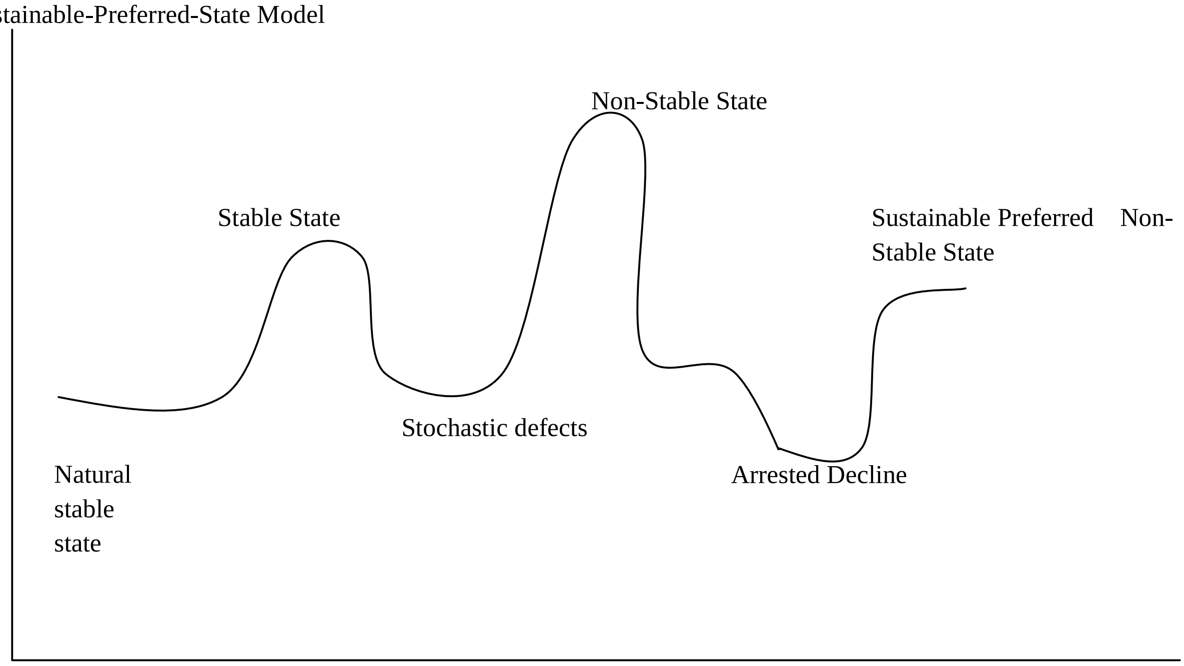

Figure 2.

Source: Modified from DeAngelis *et al* (1987)

These are given expression by: the needs of the people, which includes food security; the political as well as economic realities such as the right to subdivide plots following a successful land adjudication of a few decades ago, and the high demand for land in small parcels; as well as the biological potential of the land, which was previously underrated due to inherent environmental limitations but now enhanced through technology.

When it came to production decisions, the farmer faced many external constraints imposed by nature and market forces. Nature denotes that there wre only certain feasible ways to produce any output from a given set of input (Sonka and Patrick, 1984 in Achola 2006). The farmer sought the optimum production level given the constraints of the natural environment, and his/her response was to increase livestock herds, sometime on the pain of ecological problems of overgrazing – the inalienable consequence of overstocking. As a result, much efforts of traditional range management in the East African region were directed at prescribing land carrying capacity as the main tool of range assessment and fire ecology to control non-palatable plant species.

The social and demographic changes happening at ecological site level is placing more demand on the land; the social changing occurring at the national scale in form of advances in technology and biotechnology is helping the community to circumvent environmental limitations and improve range output by providing alternative agro landuses.

Under the emerging system of greater opportunities and wider range of landuse choices, a new approach in range management is needed [5], because land carrying capacity based on the Clementsian theory of vegetation succession cannot provide full information of what is happening in the East African rangeland today. In real terms, along with the opportunities it provides, the new management system that includes sedentary agriculture comes with a new set of environmental problems [12]. Therefore, an understanding of the operational state requires a wider perspective than those of normal range management. This study proposes the sustainable preferred-stable-state model as a broader means of range assessment to carter for the utilitarian, economic, and social needs of the land manager on one hand; and biogeographical need of biodiversity conservation on the other hand.

The East African rangelands have supported pastoralism for centuries and globally famous for wild animal conservation and safaris [3], [12], [52], [56]. But rangelands are experiencing change the world over [3], [43], [32], and in Kenya this change is most manifest though land fragmentation [27], and sedentary agriculture on the previously transhumant grazing sites [12] made possible by groundwater irrigation. Grain legume-based rotation is widely practiced under this new system and it makes scientific sense, although not necessarily in the manner that the community sees it. As it is, a new understanding of the agro-landuse in East Africa is needed to strengthen what works for the community while bringing to clear focus the tradeoffs involved in the shift from the traditional pastoralism.

Observed from the perspective of complex system theory [37], several scientific paradigms of analysis can be identified. The first-order logic in the shift from exclusive pastoral landuse to the emerging system of crop in addition to animal production is justifiable through a simple framework of how the ecosystem captures and utilizes available energy. As such, although the community does not necessarily see it that way, production of the r-strategist plants becomes more economical than effort on the k-strategy leaning livestock.

An understanding of the operating environment calls for the prudency of optimizing production at the lower level of the food chain where better energy efficiency is to be found. This is particularly grounded in the tenets of the second law of thermodynamics [28], which roughly states that: In an open system energy can be transferred from one state to another in a uni-directional process. For any process to occur, however, some energy is lost in form of heat; the bigger the process the more the entropy [28]. Some changes, however, are more productive in terms of energy conversion to biomass;

Livestock production tends towards an investment in k-strategists where much energy is used to maintain the maturity of few individuals; whereas the cultivation of annual crops is an effort that leans towards r-strategists whereby energy is transferred to many offsprings, who in turn capture more energies and matter from the environment, and convert them to biomass. The uncertain environment of risk favours the latter logic, whereby the products of the system can be harvested over a considerably shorter period of time at lesser exposure to the vagaries of environmental variables. Simply put, whereas animals can eat and eat, growing and adding slowly in meat weight, crops convert available energy into sugar and protein, and produce seeds to start a new generation within a significantly shorter period of time. As the lifecycles of crops are shorter, the periods of exposure to environmental uncertainties are less, and therefore a reduced amount of risks for the farmer to manage.

The increased soil moisture provided through blue water irrigation could as well be channelled towards forage biomass production; however, the agrarian culture of the new land owners on the rangelands favours crop production. This culture can be justified by the fact that crops need shorter time to mature and be harvested at less pain of exposure to drought, diseases, and other environmental conditions. This production system has also benefited from advances in food biotechnology, which has made available quick maturing varieties of legume and other grains especially for growing in sub-humid climates.

The second order analysis of the current conditions of the East African rangeland ecosystem has to do with the complex nature of the evolving environment. The dryland of Isinya District is no longer an open range but an ecosystem with a diversity of people. It is therefore a complex system since it now contains a community of people with complicated behaviours. Also complicated is the interrelationship between and among the biophysical components of the ecosystem, which result in emergent behaviours. The system is therefore subject to whims of the individual land managers/owners and the surprises arising out of the interrelationship between the biological and physical components under the prevailing environmental conditions dependent on factors both external and from within the management systems [29].

The natural stable-state of the rangeland is first of all disturbed by changes in weather variable sometimes manifesting as short or prolonged periods of drought. It is also disturbed by overgrazing resulting from overstocking of livestock and animals. However, despite these stochastic phenomena, the system is presumed self-adjusting [29], and should be able to revert to natural conditions, subject to the removal of disturbances, for example through periods of fallow (the fallow period at which the system is expected to recover from disturbance also represents non productive time in terms of direct economic and utilitarian interest of the range (wo)men, and needs compensating for at some point).

Basically, the system recovery is complicated by the entry of non-pastoralists, who settle in the rangeland as immigrants from land scarce humid areas, bringing with them the agrarian culture. The settlement pattern also comes with clearing and cultivation that bring about the replacement of native plant species with few agricultural plants, thus more drastic stochastic effects [29] on the old stable-state. Other less dramatic stochastic effects are also occurring through land fragmentations that result in blocking grazing movement and flow of ecosystem (genetic) vigour.

Groundwater irrigation is providing regular soil-moisture in lands that previously, at best, only received water during the bi-modal rainfall seasons around April and November. As water was the most limiting factor in the agricultural system [3] (Joss *et al*, eds 1986; Diallo *et al*., in Musila, 2008), its deficiency is now being overcome through groundwater irrigation. When this is used for crop production, as practice by the community in Isinya District, the range output is considerably increased. When this production system is maintained, a non-natural stable-state is brought about that is more profitable than the natural-stable-state [28] in terms of pecuniary and utilitarian interests of the land manager. The problem is how to sustain the increased output, and therefore profit of the new system, without eroding the native plant genetic resources.

The production system has changed from exclusive or predominant livestock production to a mixed system that tends more and more to crop productions. Its analysis requires an approach different from the usual monitoring of animal carrying capacity to provide range assessment. An analysis of how well the ecosystem is doing should also provide information on the extent to which the land owners' needs are met, and the extent to which the natural system is protected to carter for the future needs of the biological as well as the cultural diversity of the area. It is a changing system – a nonequilibrium system best described using the state-and-transition models [6], [8].

One state-and-transition model that is fairly-suited for the analysis of the changing East African rangelands is the self-organising holarchic open system (SOHOs) as developed and described by [28] as well as [29]. This model states that the ecosystem is self-organising, and different operating states can be expected to emerge. Each operating state represents the physical and biological history of the area, and reflects the desire and therefore the effort of the landowner to direct production using innovation and opportunity provided by technology. No operating state is better than the other, for what is best depends on landowner's choice. The role of science, therefore, is not to promote any landuse or operating state over another. Rather, it is to describe each operating state through narratives, and in so doing, the tradeoffs between choices of landuses or operating states is teased out. Kay and Ragier (1999) used the SOHO model to explore and identify possible operational states of a soft maple swamp ecosystem in Canada. Ideas provided by Kay and Ragier which can be borrowed and modified to identify and delineate multiple operational states of the East African rangelands today.

While the various state-and-transition models mentioned above justify the multifunctionality of the range environment, the biogeographical concern of biodiversity erosion in the modified operational state is informed by the physical context of the habitat theory. According to [9] habitat theory states that: “Physical change is hypothesized to be the ‘kick’ that initiates speciation”. Whereas under the agro operational state no speciation is to be expected, the theory does provides useful insights on the role of context in community composition. The human organized physical context can sway which species take part in the competition leading to succession. According to [9] therefore: “The physical context has a strong influence on which organism can live in a given place and how evolution can proceed therein”.

This study draws from the first and second-order analysis of the changing range landuses as described above partly using some state-and-transition models. Combining these with the information gained through passive observation of what is happening at the community level, and guided by the habitat theory, the study proposes the sustainable preferred-stable-state model as a means of analysing the agricultural lanuse changes in the East African rangelands.

The sustainable preferred-stable-state is not a pre-defined state. Rather, it is a condition defined by the management objective given the limited range of choices available to the landowner, and the stewardship towards the conservation of the biological (reproductive) elements (plant or animal) within the system which will lead the successional restoration. In the system under focus, the successional regeneration is expected to occur during periods of fallow or abandonment.

Whereas the aridity condition is the common defining feature of the East African rangelands, given the opportunity of choice provided by technology, the landuse decision now depends on the preference of landowner/manager. For example, the choice could be livestock production as is still widespread; wildlife conservation, as is the case with many conservancies in the region; or cultivation, which is gaining fast in popularity.

It can be speculated that the aims of management include sustainable cheaper cost of farming and higher yield of crops. The sustainable preferred-stable-state can help to achieve this, and in practice this achievable through community initiative of

irrigated legume-based rotational farming, which potentially confers the co-benefits of: biological nitrogen fixation; increased pollinator insects visitation, therefore, proper pollination of crops; followed by the science based reporting that could sensitize the community to conserve soil seed bank through fallow.

The notion of balance of nature has long been discarded by scientists [13]. Demographic and cultural changes are presenting stochasitic forces to shift the equilibrium of the East African rangeland, and resulting in new forms of stable state [13]. Through innovations, the present occupants are creating a socio-ecological productive landscape [17], [57], and it is upon range management to provide a guide through the weight science-based reporting to make the system work. Shift without the benefit of scientific knowledge can tilt the cultivated range ecology to a threshold beyond autogenic recovery, and balance of nature would be directed in a totally new direction in terms of biotic composition of the ecosystem [6], [7].

As the demographic landscape changes, so do the economic and cultural considerations driving landuse decisions. As land occupation becomes more sedentary, the agricultural landuse choice is likely to move towards crop production, or a mixed system that includes cultivation, forage and animal productions. In order to maximize own welfare given expression by utility or cash incomes, the landowner operated in risk-free environment and chose the farming system best suited to her/his needs (Achola, 2006). In these situations in the dryland, water was almost always the critical limiting agricultural input (Joss *et al*, eds 1986; Diallo *et al*., in Musila, 2008). The shift towards crop or a mixed system production is enhanced where there is affordable access to blue water (FAO, corporate repository), irrigation system, and improved cultivar and perhaps farm credit. Most of these components are now available to farmers through research and development, as well as through government, NGOs and private sector initiatives. However the economic costs of organic and inorganic fertilizers remain a constraint. Despite that, rangeland farming is now an everyday reality in Isinya District.

Even then, the predominant lifestyle strategy of the indigenous pastoral community remains livestock herding, regardless of the fact that some of the pastoralists have temporarily adopted cultivation to make ends meet. The assumption is that in years of favourable weather and in times of high livestock demands at attractive meat prices, the pastoralist will almost certainly return to livestock grazing as a preferred means of livelihood.

The community is showing the innovative way to make the range more productive through irrigated farming. That is the direction they want to move, at least temporally. It is the role of science to support this shift to socio-ecological production landscape [17], [57], which brings livelihood and economic benefits to landowners, as well as income for women through farm labour employment. In doing so, science must also provide information about cost to natural biodiversity.

The range climate is naturally best suited for yields of forage and herbaceous; livestock keeping will always be an alternate source of livelihood, despite temporal change in strategy occasioned by socio-ecological changes. Sometime in the future, it is possible to envision the ecological, cultural and economic needs to return to pastoral lifestyle. Such return could be easier in a situation where the natural range vegetation is still intact to re-colonize the new system.

An understanding of the operating system calls for a new approach in range management, which may help the land manager to optimized range output while addressing the biogeographicl concern of biodiversity erosion. The study draws from the first-order analysis of production at the lower level of the food chain, and the state-and-transition model as described by [6], [7] and as modified through the self-organizing holarchic open system of (1999) as well as [29]. Combining these with the knowledge of the management system in the Isinya District and guided by the habitat theory [9], the study advances the sustainable preferred-stable-state model as a means of understanding range landuse change in Kenya and East Africa. The framework promotes community innovation and agility [40] and resilience-based management [8] aimed at achieving sustainagility [40], and therefore a sustainable preferred-stable-state of socio-ecological production landscape [17], [57].

The sustainable preferred-stable-state is best described using a case study. The case here evaluates irrigated legume-based rotational system and its effects on rhizobia and pollinator insect diversities, as well as the soil seed bank in a rangeland ecosystem in Kenya. Concern about rhizobia and pollinator diversities are for their ability to increase crops, companion crops, and sequential crop yield while reducing the need for inorganic fertilizer input. This should thereby make farming affordable. The concern for soil seed bank is based on the assumption that the seeds stored in the soil will lead the successional restoration of range vegetation during fallow or abandonment- provided the farming system takes measures to control its erosion.

Irrigation is the main input that makes the farming system possible since it is the only viable way to maintain soil moisture. As such the comparison between the range types is meaningless during wet period when soil moisture is just about uniformly available. Nonetheless, the study will be carried out at least over one wet and one dry season, so that the effects of irrigation on the attributes can be observed with clarity during the dry periods.

Key for the Stable-State ModelPreferred -tate-and-transition model:

Stable state: Savannah-grassland: Livestock herding, wildlife production, wildlife corridor and dispersal
Change push factors: High Population in humid area, limited humid area for agricultural expansion; poor environmental condition bringing about low range output; low value assigned to rangeland leading to subdivision and selloff at affordable cost, settlement of urban dwellers and people form humid regions due to availability and affordability of land.
Economic attractors: Available land, affordable land, fertile soil and subdivision in small parcels; willingness to sell due to perceive low value after years of drought.
Ecosystem modification: Land fragmentation and fencing; disappearing open range; difficulty in movement of livestock and herdsmen low access to forage from a diversity of landscape limited option for settlers.
Transitional state: Cultivation by settlers. Pastoralist adopting agriculturalist strategy. Technology: better seeds, farm credit financing. Irrigation packages. Agricultural extension.
New biophysical state: The emergent state to compare with expected state Soil-moisture availability. Year round patches of croplands. Change in species composition. Weeding to improve crop performance. Soil seed bank erosion.
Sustainable Preferred state: High yield of agricultural plants under irrigation. Better food security at household levels. Viable store of seeds in the bank to lead successional restoration of range vegetation during fallow, and linked to open range through dispersals.

V. Problem Statement

Rangelands produce a wide range of economic and ecological goods and services. Among these are a host of ecosystem services important to people (Havstad, 2007 in [51]), [5], meat for human consumption, tourism-important wildlife and game hunting opportunity.

Schematic Representation:

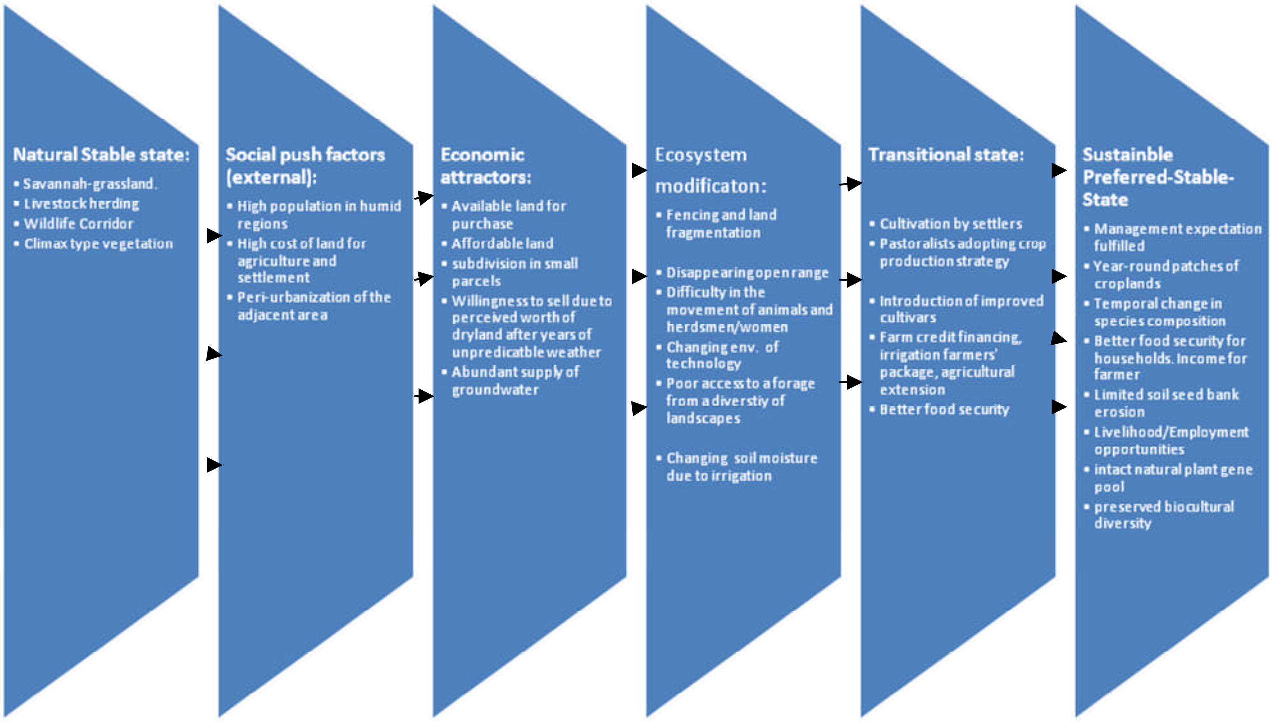

Figure 3: Possible Range Operational States (Source: author)

Since recent years, the ability of rangeland ecosystems of East Africa to maintain these goods and services provisioning has been steadily declining. The problem is better pronounced during prolonged droughts, when much of the animals are lost due to shortages of food and water. Partly to blame is the generally low ground cover resulting from over grazing and human induced modification [51]. Overall, with less vegetation cover, the rangelands cannot now be relied on for carbon storage to mitigate climate change [51]), [53] as such, less ecological and economic value of the total ecosystem services. Range fragmentation further adds to the environmental problems leading to low range output, because it limits animals' access to the heterogeneity of forage accessed from different landscapes to make up for shortages in the home range. Fragmentation is occurring through land subdivisions (Kenya Ministry of Environment and Natural Resources, 1994). This arises from increasing settlement of people migrating from high population areas. The trend is that new settlers come in, buy land in small parcels [27], build homestead, cultivate the remaining space (rain-fed or irrigated), and erect fences to protect crops. This trend is not only reducing the relative size of land under traditional pastoralism, but also limiting wildlife migration corridors and blocking movement of grazing animals to their foraging areas (Kenya Ministry of Environment and Natural Resources, 1994), [27]. Pastoralists in the affected range areas still maintain their traditional lifestyle, albeit under difficult circumstances. The inherent enculturation of the new settlers from humid regions is that of crop production, and pastoralists have also changed their livelihood strategy, some by adopting crop production practices in order to make ends meet. The overall agricultural landscape of the in the Isinya District range units is increasingly shaping up to fragments of cultivated lands, but pastoralism still persist as the dominant form of agriculture. However, transhumant pastoralism is greatly disturbed in the area by range fragmentation caused by encroachment of human settlement and agriculture. Land fragmentation is also generally felt at the national level as one of the single most important threats to genetic erosion (Ministry of Environment and National Resouces, 2000). Social changing is diving livelihoods strategy, all within the range environment. Irrigated farming in the non-arable lands of Kajiado is now an ongoing practice; the concern is how to make the shift in landuse work for the farmers in the long run, while helping to conserve natural plant biodiversity that supports the pastoral culture of the indigenous community.

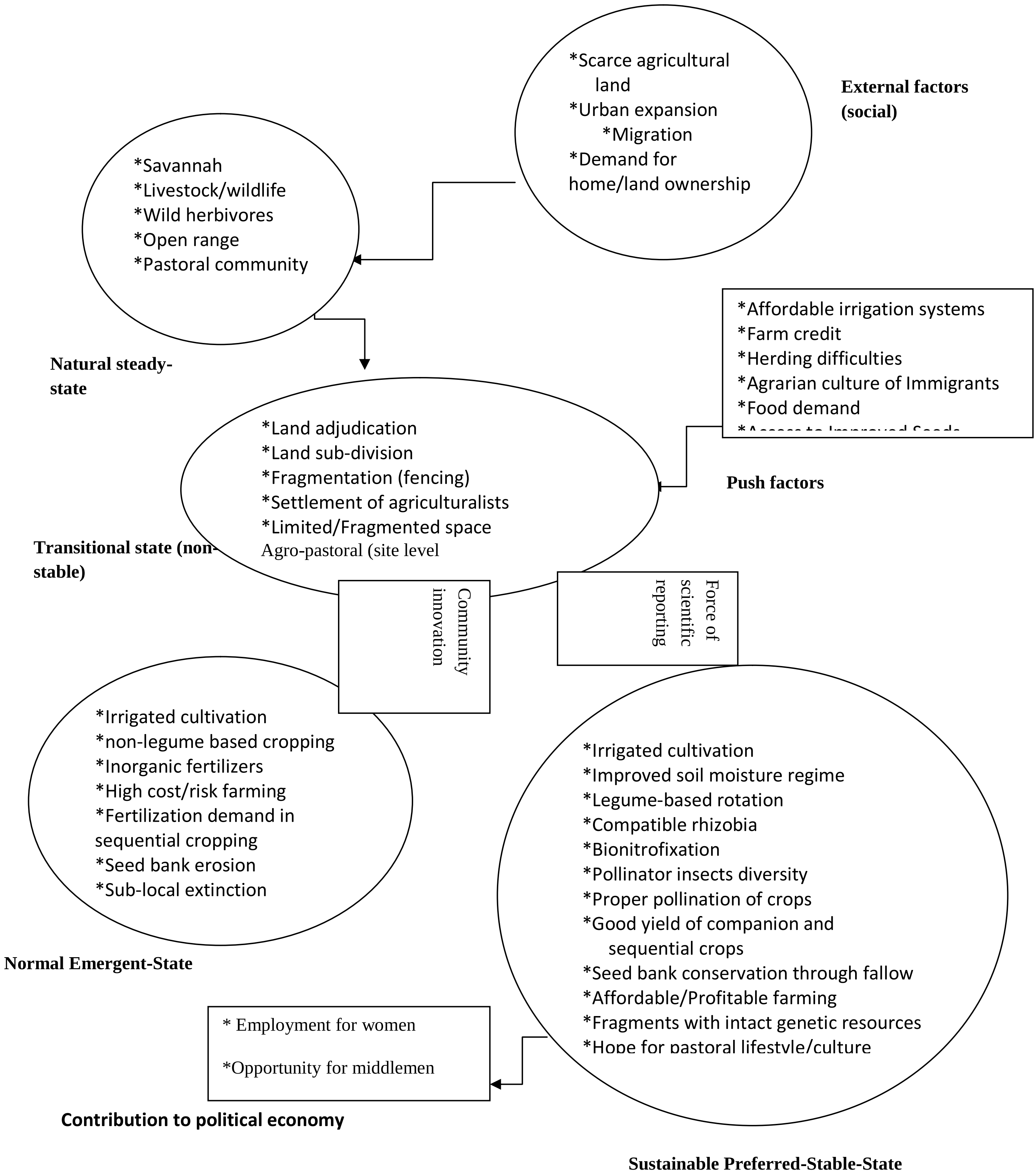

Figure 4: Sustainable-Preferred-State model (source: author)

In the Isinya District area, the adoption of livestock herding lifestyle in the past was a response to the aridity condition, which naturally favours the management of grazing animals to harvest grass and other herbaceous vegetation available in the dry environment. It was a landuse strategy dictated by limited soil moisture (Joss *et al*, eds 1986; Diallo *et al*., in Musila, 2008). Now, it appears as though the present inhabitants of the area have circumvented this limitation through the use of groundwater irrigation to maintain adequate soil moisture in the cultivated sectors. To maximize the benefit of this, natural vegetation which provided the normal forage for livestock and wild animals is cleared and replaced with quick maturing plants with direct nutritional and economic value to people. In other words, grain legume crops, maize, ther market gardening plants, and even cash crops are introduced in places of natural vegetation.

At the landscape level, the general concern includes the erection of physical barrier and the clearing of surrounding natural vegetation, which filter some species from the remaining open range areas (Kenya Ministry of Environment and National Resouces, 2000). It is therefore hypothesized that the push effect of agricultural landuse encroachment results in the isolation of remaining the areas still intact with natural biodiversity, given the broken contagion arising from fragmentation [38].

In the new management system, the biogeographical concerns include the diversity of species that play a significant role in crop yields and how these can be controlled to increase farming output. It is also about the availability of wild genetic material in seeds of the natural vegetation which have known evolutionary linkages with the animals, and connected with people through ecological and economic importance, valued and yet to be valued.

In general terms, the study hypothesizes that the change in soil moisture regime over the normally dry lands and the transformation of vegetation composition could have some ecological effect on soil mega and microorganisms, as well as having direct consequence for some terrestrial organisms.

As it is, irrigation and biotechnology are making dryland farming possible, and legume-based rotation could improve crop yield through biological nitrogen fixation and by attracting insects with capacity to pollinate the field. However, the study hypothesises that continuous cropping and inherent weed management method could potentially erode the soil seed pool beyond a critical threshold. Threshold here implies: “That the integrity of the range site may not hold in the long run, and vegetation succession may produce a different set of climax type community which excludes natural plants” [8], [32]. The emerging socio-ecological production landscape should be managed in such a way that natural plants gene pool are not left out in sucessional restoration to occur in the opportune times of fallow or abandonment.

Essentially, insect pollinators and rhizobia are keystone species in production ecosystems due to their ecological functions [38], and soil seed bank is a foundation for natural system conservation. Although there is an appreciable level of *ex situ* seed conservation in Kenya and East Africa, species must ultimately exist in natural settings, within functioning communities and ecosystems, interacting with abiotic factors of the environments [38]; thus allowing for a fuller expression of genes.

Experience gained elsewhere about rhizobia [4] [19], [36] and knowledge of pollinator insects ecology [14], [18] can inform science-based advice passed on to the community to make farming more affordable and profitable, through biological nitrogen fixation and proper crop pollination, respectively.

The desirable outcome is to increase food output in the production ecosystem, and this is biologically possible if the right strains of rhizobia are present to nodulate legume roots and fix atmospheric nitrogen [4] [19] - which in theory can increase crop yields [11] - and if abundant pollinator insects are present to forage and pollinate the crop field. All these are foreseeable under the condition of regular and adequate soil moisture regime made available by groundwater irrigation (Phiri, 1984).

For science and management purposes therefore, it will be useful to test whether the favourable biological condition provided through the introduction of regular soil-moisture and legume crops increase the population of rhizobia in the rhizosphere, even after legumes have been harvested.

Similarly, insect diversity and abundance are known to increase in drylands after rainfall [3] [13]. However, little is known about the relationship between regular, year-round soil-moisture supply through irrigation and the diversity of pollinator insects in African drylands. This problem is of considerable importance, and the central issues are irrigation, and the overriding importance of legumes [42]. Change in soil-moisture regime of the dryland, and the resulting large patch of nectar- rich, irradiant flowering crop legume field, should in theory attract a diversity of pollinator insects. The study examines this hypothesis, which potentially strengthens knowledge to guide science base reporting as well as extension service to the community.

Conversely, the desirable condition to conserve natural vegetation can be achieved by limiting soil seed bank erosion [2], [15]. The study hypothesizes that in the cultivated areas, seed pool is eroded by the crop weeding practice that destroys natural plants at nascent stage before the cycle of germination, growth, and seeding are completed. This concern pertains to the conservation of plant biodiversity

Irrigation entails reliable soil-moisture in the rangelands of East Africa, which at best, only received water during the biomodal rainfall seasons. Grain legumes are important not only for their yield of large quantities of protein [42], but also their irradiant flowery quality that attracts pollinators and their roots ability to fix nitrogen in association with rhizobia. Moreover, legumes such as field beans are among the most important grain crops in East Africa.

Biological nitrogen fixation (BNF), if well understood and controlled, will save farmers the economic cost of inorganic fertilizers and the ecological cost of ground and surface water pollution [42]. If study finds that the diversity of nitrogen fixing rhizobia increases in the rotational cropping system and the abundance remains high even after legume crops harvest, then more farmers can be encouraged to repeat the cultivation of pulse in sequence, before the introduction of maize. The usual practice is maize cropping in sequence to beans, and although maize is an important crop, it is useful to increase the output of pulse. This is not just because grain legumes are a vital substitute to meat protein in households' diet, but also because they are more likely to benefit from an environment of abundant compatible rhizobia.

If the study finds that the native rhizobia are not compatible for *bionitrofixation* in symbiosis with legume roots, then local farmers can be advised about possibility of obtaining the right strains of efficient inoculants to treat the soil prior to planting of grain legumes.

Likewise, it will be useful to know how significant presence of flowering legume crops may affect the diversity of pollinator insects in the area. The diversity of pollinators has a direct relationship with grain yields [13], [18]. Among the pollinator insects, honey bees are important pollinator insect species. According to the study anticipation, a positive relationship between flowering legumes and bee diversity increase may inform future location of apiary in the area. Access to a rich source of nectar will increase honey yields, thus making bee keeping more profitable. It will encourage more farmers to adopt this additional diversification option. Thus, the reliable source of nectar in field legume flowers can provide a co-benefit of supporting bee keeping.

Then, at the end of the day, despite the current trend in landuse towards agricultural practices, livestock keeping remains the primary and traditional rangeland use in the Kajiado area. For the indigenous pastoralists of the area, livestock herding remains a livelihood strategy as well as culture. The ecosystem approach demands that people and their culture be at the heart of landuse decision [33]. As it is, for cultural and economic reasons, it is unlikely that Maasai and other indigenous herdsmen will completely give up their lifestyle of livestock herding any time soon.

In other words, despite the land being, at the moment, cleared of natural vegetation and cultivated with crops, it is reasonable to expect that indigenous pastoralists would like to see the land return to range conditions at some point in time. Such a return is only possible if natural vegetation of the rangeland re-establishes through successional regeneration. And it is only those seeds and other plant growing parts, which happen to be in the soil at the time of succession that will participate in the competition and possibly colonize the emergent climax community [8] [9]. As such, it is important that viable seeds, rhizomes and other growing parts of grasses, herbaceous, and savannah plants in general be sufficiently present in the soil during periods of abandonment fallow. However, the incessant weeding of nascent plants in cultivated areas potentially threatens to erode the soil seed bank beyond the critical threshold, thus making return to range condition likely slow in future if not impossible. Hence the study to ascertain the effects of irrigation farming on the diversity of the soil seed bank.

New range management objective supposedly include sustained high yield of crops and at low economic and ecological costs, while keeping the option open for the return to range conditions and within the immediate means of range managers. It is to harness shift to multifunctionality, to encourage farmers to be agile to new opportunities through innovation, and to keep the system sustainable. It is the sustainagility framework popularized by Patrick Dixon, and described by [40].

Noordwijk (2009) ponders on segregation and integration for multifunctionality within a socio-ecological space. The sustainable preferred-stable-state model postulates that segregation in time – of fallow and abandonment - can achieve multifuntionality of space. Of course, this is provided the holon components [28] remain significantly present during the intervening state of fallow or abandonment. In the rangelands, the most important of these components are the soil seed bank and other growing parts that can reconstitute the natural vegetation community.

This management principle is not entirely new in East African conservation management. For example, the environmental planners of the Bamburi Company, learning from past experiences of ecosystem restoration at Haller Park, Mombasa, now keep stock of soils remove at excavation sites. These soils then provide the bedrock of future restorations, so that the ecosystems that emerge will bear close vegetational resemblance of the old order. Ecosystem cannot be restored in particular but in identity. Identity marked by dynamic vegetational community with constituent animals foraging and exploring the system for habitat, staging, mate, energy and materials with a significant level of integrity, if not better than the old domain being mimicked.

By and large, the range landscape is changing, and the community is adapting through innovation to make things work. Adaptation is mostly through irrigated farming of improved cultivars developed to withstand harsh dryland conditions. Science can make the process more efficient and sustainable, so that instead of lamenting rangeland use change, ways can be found to help the land users succeed by creating productive socio-ecological landscape [17], [57]. The study could generate new ideas to inform its science based reporting through narratives for the benefit of decision makers, extension, and farmers.

The problem under investigation will respond to the following research questions: (a) Is there a significant variation in soil moisture among the range types due to irrigation? (b) Does rhizobia diversity vary in soils among range types due to irrigation? (c) Does rhizobia diversity increase in range soils with grain legume plants and remain high after crops harvest? (d) Does pollinator insect diversity vary among range types due to legume-based irrigated farming? (e) Does soil seed bank changed with range types due to destruction of weeds at nascent stage? (f) Does soil mega nutrients composition vary among the range types?

VI. Objectives

Overall objective:

To determine the effects of legume-based mixed cropping under irrigation on the biodiversities of pollinator insect, rhizobia, and soil seed bank in a cultivated rangeland.

Specific objectives: (a) To determine the effect of soil-moisture on legume nodulation by rhizobia in irrigated rangeland soils. (b) To determine whether the abundance of rhizobia remains high in the soil after grain legumes harvest (c) To determine whether pollinator insect diversity varies with presence of flowering legume plants in dry seasons. (d) To determine whether continuous weeding of natural plants at nascent stage will erode soil seed bank in rangeland cultivated under irrigation. (5) To assess the overall effect of irrigated cultivation on soil nitrogen and phosphorous.

VII. Hypotheses

Main Hypothesis

Irrigated, grain legume based rotational cropping has no effect on the diversity of pollinator insects, rhizobia, or soil seed bank in rangelands of Isinya District.

Specific Hypothesis

Ho_1: Nodulation of legumes by rhizobia does not vary with soil-moisture due to irrigation in rangelands.

Ho_2: Rhizobia diversity does not significantly change in the rhizosphere after irrigated legume crops harvest in rangelands.

Ho_3: Presence of flowering legume plants does not influence the diversity of pollinator insects in rangelands.

Ho_4: Continuous cultivation in rangelands under Irrigation and the weeding of nascent natural herbaceous does not affect soil seed bank.

Ho_5: There is no relationship between irrigation farming of legume with other crops on the phosphorus and nitrogen composition of soils in rangelands

VIII. Results and Observation

Kajiado District

What is now known as Isinya District had until recently been one of the divisions within what was Kajiado District of Rift Valley Province, Kenya. Following the enactment of the current Kenyan constitution in August, 2010, Kajiado District was elevated to the status of a county and Isinya Division was likewise elevated to Isinya District at least on a temporary bases to form an administrative unit within the county. Kajiado County in which the Isinya District is located lies between longitudes 36^0 5’ and 37^0 5’ east, and between latitudes 1^0 0’and 3^0 o’south. Kajiado County covers an approximate area of 15,546 Km². In the north, the district is bordered by Nairobi, Kiambu West and Naivasha Counties; and by Machakos, Kibwezi, and Nzau Countis to the east, as well as by Narok North and South, and Loitokitok counties to the west [31].

Three distinct topographic features generally characterize the physiographic conditions of Kajiado

County area, namely: Rift Valley, Kapiti, and Central Broken Ground [31].

The Rift Valley describes the low depression running northwestern and southwest of the County. The depression contains important features such as the soda ash rich Mount Suswa and Lake Magadi. The altitude in this area ranges between 500 – 2000 meters asl [31].

The Central Broken Ground comprises the 20-70 kilometres wide stretches that runs north between the northeast and southwest of the district. This is an area of mid altitude between 1220 – 2070 metres above sea level [31].

The (Athi) Kapiti plains primarily consist of gently undulating slopes that become rolling and hilly towards the Ngong Hills. The hills form catchment areas for the Athi River whose main tributaries are the permanent Mbagathi and Kiserian Rivers [31]. These rivers are important sources of water for domestic uses and livestock, as well as for small and medium-scale agriculture in the neighbouring Greater Kajiado area. A segment of Isinya District is drained by the Isinya River [41], which is a source of water for domestic use and the growing practice of crop production in the adjacent areas.

Precipitations in the district normally follow the pattern of the Kenyan bi-modal rainfall seasons. Up to 50% or more of the recorded rainfall in the area occur during the March-May season, and about 30% is recorded during the October-December season [31], [41]. Therefore, although the annual rainfall is generally low, it normally exceeds the threshold of "effective precipitation" [3] required to support annual and perennial grass, herbaceous as well as shrubs. With proper timing, this amount of rainfall also supports dry cultivation of staples such as maize and field beans. However, the risk of crop failure is always imminent.

Temperature in the district ranges between 22^0 C and 34^0 C. This reliable temperature range results in high surface evaporation under the condition of generally low precipitation. This regime basically produces an arid climate, characterized by low tree cover with grass and shrub domination. The district can therefore be grouped under Kenya's agro-ecological zone IV-V according to the Pratt and Gwynne (1977) classification.

As a pastoral area, the Kajiado District was predominantly occupied by the Maasai people, with semi-nomadic lifestyle. However, both the lifestyle and population are undergoing changes due to land adjudication and the practice of group ranch sub-divisions [31]. This has resulted in the increase in land sales, and immigration of people from the land scarce agricultural zones, and among urban population looking for affordable space to build own residential houses. The later is happening particularly due to the district's proximity to Nairobi [31], and the even more proximate peri-urban areas such as Ngong. Kitenkela and Isinya divisions, which make up the District are also witnessing absolute and relative population increases. According to the 2009 Kenyan census figures, human population and household numbers in these areas more than tripled over the last ten years.

Study Site: Isinya District

The study sites fall within the Isinya District which comprises: Kitenkela, Ongata Rongai, Olturoto, and Isinya Locations.

The African Highway passes through Isinya District linking Kenya with Tanzania, Uganda, and other countries in the eastern Africa region.

The Isinya District is located in southeastern part of Kajaido County of Kenya. It is a typical rangeland, classified as Kenyan ecological zone 4 according to Pratt and Gwynne (1977). It is therefore characterized by average annual rainfall of about 450 mm, as well as tropical high day time temperature and evaporation. Its soils are mostly shallow and underlain by kapiti phonolite basement rocks, which make the establishment of large dry forest difficult. The vegetation feature is therefore savannah, which is naturally suited for livestock and wild herbivores production.

The Isinya is only about 40 minutes south of Nairobi by a car drive, therefore a targeted area for urban expansion, and it is already providing night time residence for a good number of urban workers in the Kenyan capital, Nairobi. Although previously a wildlife migratory corridor between the Nairobi and Amboseli National Parks, the Isinya is witnessing rapid change in landownership due to the peri-urbanization of its adjacent areas.

Agricultural landuse in the area tends to be shifting towards crop production, as livestock herding is less and less viable. However, semi-nomadic pastoral practice remains the predominant lifestyle in the area, despite the increasing change in demographic distribution as a result of immigration.The physiographic feature of the area is characterized by abundant flow of groundwater, which is now exploited for crop production throughout the year.

IX. CONCLUSION

Change is occurring daily in the agricultural landscape of East Africa. The factors driving the transformation are both external and internal, and these include the absolute and relative human population and demographic changes happening within and on the fringes of the rangelands; variation in weather patterns; increased resolve to improve the range output through innovation; and help from progress in technology and biotechnology. The community is changing the fortunes of the land by adopting cultural experiences gained from the humid agrarian zones of the immigrant population; by circumventing water deficiency through more accessible and affordable irrigation technologies; and biotechnology has helped through production of cultivars improved for dryland cropping. The community is leading the way and the role of science is to observe, to listen, to learn; and to bring in knowledge gained elsewhere to produce reports gathered through the wealth of science based methodologies.

The aim is to help the community succeed in their innovative endeavour to achieve food security while conserving biological and cultural biodiversity. The study does not promote any big new idea, but the small things that could be done more within the framework of the existing cropping systems to improve farm outputs and minimize the erosion of seeds and propagules of native plant species present in the soil. It examines the changes in rhizosphere in a legume-based system in order to better understand how this could lead to a better budget of biological nitrogen fixation (bionitrofixation) as a supplement (not complete replacement) to inorganic nitrogen-based fertilization; and on pollinator insects for their role in proper pollination of crop to increase fruit yields.

It further examines the effect of weeding system in the area on the abundance of soil seed pool, which is an *in situ* repository of native plant genetic resources. These genetic resources form the basis for pastoral agriculture, and therefore the culture of the pastoral communities. Further, the future of biotechnology is also partly dependent on these wild genetic materials. This future can be safeguarded through the conservation of soil seed bank.

What is happening in the East African rangeland is a community driven landuse change, and one that could be supported and managed well rather than lamented. It is a social issue because its origin can be traced to demographic changes; it is a cultural issue because it can be seen as lifestyle turned upside down for the pastoralists – although such conclusion cannot be reached in the advance of knowing how shift is perceived by the community. It is an issue of political-economy because it provides trade opportunity for fresh produce middlemen/women, seed and agro-input multinationals, and for farmers. It is an issue of gender justice because it is providing more employment opportunity for women whom are favoured in the farm works of planting, weeding, harvesting, and grading of French beans for export - thanks to local perception of female persons as better predisposed to provide these labours. It is about public health because it is contributing to national food security, while also providing protein alternative in households' diets. It is economics because it potentially makes farming more affordable and profitable through lower cost of fertilizer input and higher yield of crops through efficient pollination....The enquiry is biogeographical in nature, and thus uses multidisciplinary, interdisciplinary as well as trans-disciplinary approaches to monitor what is happening to agricultural and wild plants biodiversity in the study area.

The study interest in landuse change focuses on local agricultural landscape of the East African rangelands; however, it can be replicated across Africa and from all those places where scholars are reporting similar rangeland use transformation. Overall, the scale of monitoring which can inform this scope of reporting goes beyond the traditional approach of range management. New approaches are needed and the study proposes the sustainable preferred-stable-state model as one such method.

Managers can aim for a sustainable-preferred-state, and future studies can help by setting criteria to measure deviation from that state; and find ways of creating ecological linkage/network/flow between the fragmented units thereby increasing genetic vigour, and overcome loss effect within the patches. A main aim of this study is to lay foundation for sustainable-preferred-state model, to explain it through site reporting, and to make the narrative more understandable through examples from an actual field experiment.

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